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Neutral Grounding Surge Protection - Generator Surge Suppressor

BACKGROUND

[0001] The concepts/arrangements described herein relate generally to a drilling vessel power transmission system, and more particularly, to a protection circuit for the main electrical power generating and distribution plant in a drilling vessel.

[0002] A power generation and distribution system aboard a drilling vessel generally utilizes diesel-driven generators to provide power to various loads involved in drilling operations, positioning the vessel, and the like. Such power distribution systems typically include three (3) interconnected switchboards capable of being configured as a single power station or two or three individual power stations. The power generation and distribution system is fully enclosed within the steel hull of the vessel, acting essentially as a Faraday cage protecting the system components against undesirable power surges induced by external sources (e.g., lightning strikes, geomagnetically induced current (GIC), and the like). However, voltage surges may also be caused by malfunctioning equipment within the power transmission system, for example, circuit breaker single-pole failures, switching transients, intermittent ground faults through high inductance (e.g., instrument transformer failures to ground), and the like.

[0003] Traditional approaches to surge protection in these circumstances involve use of a surge protector installed within the main electrical switchboards connecting the generators to the load distribution feeders. However, for a drilling vessel power generation and distribution system, this introduces the risk of a single failure on the main bus with potential for a main power plant blackout (i.e., loss of station keeping ability) and can interfere with the protection system with the potential to cause undesired loss of power to essential equipment during critical operations.

[0004] It is desirable to provide protection for a drilling vessel power transmission system against surges caused by power plant equipment malfunctions, while avoiding exposing the generators or other aspects of the system to unexpected failures or undesired operation of protection devices.

BRIEF DESCRIPTION OF THE FIGURES

[0005] For the purpose of illustration, there are shown in the drawings arrangements which are presently preferred. It should be understood, however, that the concepts/arrangements are not limited to the precise arrangements and instrumentalities shown.

[0006] In the drawings:

[0007] Fig. 1 is a schematic block diagram of an example drilling vessel power transmission system;

[0008] Fig. 2 is a schematic block diagram of an example surge protector configuration from the drilling vessel power transmission system of Fig. 1 with a grounding scheme including a high resistance connected between each of the main generator neutral and the vessel hull grounding;

[0009] Fig. 3 is a schematic block diagram of an alternative example of a surge protector configuration from the drilling vessel power transmission system of Fig. 1 with the same grounding scheme as shown in Fig. 2;

[0010] Fig. 4 is a schematic block diagram of an alternative example of a surge protector configuration from the drilling vessel power transmission system of Fig. 1 with an alternative grounding scheme including a high resistance grounding transformer connected between each one of the three (3) main distribution switchboards and the vessel hull grounding; and

[0011] Fig. 5 is a flow chart illustrating an example for integrating the surge protector of any of Figs. 2-4 in the main electrical power generation and distribution protection system.

DETAILED DESCRIPTION

[0012] Referring to the drawings in detail, wherein like reference numerals indicate like elements throughout, Fig. 1 shows an example arrangement of a drilling vessel power generation and distribution system 100 according to the present concept. The power system 100 may include one or more generators 102. Each generator 102 may be driven by a generator prime mover (not shown), such as a diesel engine or the like, although other types of power generators may be used as well in keeping with the concept. In the particular arrangement shown in Fig. 1, three generators 102 are utilized, each providing power to a respective switchboard 108 through a connecting bus or line. A generator circuit breaker 106 may be positioned between each generator 102 and the respective switchboard 108. The power system 100 may include more or fewer connected generators 102, as necessary to meet the vessel electrical power demand. In addition, it is possible to have more than one generator 102 connected to a particular switchboard 108, either for providing redundant power generation capabilities or for providing additional power for distribution. It is further possible to connect a generator 102 to multiple switchboards 108, where necessary.

[0013] Each switchboard 108 may be powered by one or more generators 102. Each switchboard 102 may be coupled to multiple step-down voltage transformers 112a that each provide electrical power to the vessel electrical loads 112. Each distribution transformer 112a may be protected by a feeder circuit breaker 110 and have its high voltage (HV) winding connected in Delta. For example, loads 112 may include conventional shipboard, drilling and propulsion auxiliary loads supplied through low-voltage distribution switchboard (e.g., lights, motors driving cooling, ballast, fuel transfer, drilling fluids pumps, ventilation fans, or the like), and major drilling and propulsion consumers supplied through variable frequency drives (VFD) switchboards. Individual switchboards 108 may be dedicated to operating different loads 112 on the vessel, although certain loads 112 may be connected to multiple switchboards for reasons such as redundancy, or the like. Although three switchboards 108 are shown, more or fewer switchboards 108 may be utilized in the power generation and distribution system 100, as per each individual vessel design.

[0014] Switchboards 108 may be electrically connected to one another via bus-tie cables 114 for purposes of sharing power, redundancy, or the like. In Fig. 1, the bus-tie cable 114 at the far left of the figure may tie to the bus-tie cable 114 at the far right of the figure, i.e., connecting the left and right switchboards 108, although these bus-tie cables 114 may instead connect to additional switchboards 108 not shown in the drawing. To enable isolation of the switchboards 108, for example in the event of a power surge, an error in one of the switchboards 108, or the like, bus tie circuit breakers 116 may be utilized in the bus-tie cables 114.

[0015] Additional circuitry (not shown), including transformers, energy storage devices, power conditioning circuitry, and the like may be included in the drilling vessel power generation and distribution system 100 as well, where necessary. In addition, the loads mentioned above are exemplary only, and others may be utilized within the drilling vessel power generation and distribution system 100, as necessary.

[0016] Referring to Fig. 2, in some arrangements, a generator 102 may be connected to ground 127 (e.g., hull grounding of the vessel or the like), particularly using a neutral grounding resistor 130. In the example shown in Fig. 2, the generator 102 is a three-phase generator rated for 8438 kVA and 11,000 V at 60 Hz, and the neutral grounding resistor 130 may be designed to limit ground fault to a maximum of 10 A. However, the neutral grounding resistor 130 may be designed for other maximum current ratings, based on the total leakage capacitive current of the main power plant components (as defined in applicable standards, rules and regulations), that is: the sum of all leakage capacitive current of all generators, all bus-tie cables and all feeder cables connecting the main switchboard 108 to each of the distribution transformers 112a. The low voltage system leakage capacitance is not accounted for when sizing the neutral grounding resistor since all transformers that provide electrical power to these consumers have their three- phase windings connected in Delta.

[0017] To protect the power system 100 against the undesired effects of voltage surges caused mainly by equipment malfunction or like faults, the drilling vessel power generation and distribution system 100 may incorporate a surge protector 128 connected between a neutral point 129 of the generator 102 and the ground 127, in parallel with the neutral grounding resistor 130. The surge protector 128 may include a metal oxide varistor (MOV), although other types of varistors or like switching solid state devices may be used as well for conducting large currents on demand. In normal operation of the power generation and distribution system 100, any three- phase current unbalance, caused either by loading unbalance, by a phase-to-ground shunt failure or by series single pole closed failures will flow into the ground 127 through the neutral grounding resistor 130. The unbalance current flowing through the neutral grounding resistor 130 will cause a voltage drop across the neutral grounding resistor 130. This voltage drop is monitored by the surge protector 128 and, if the voltage across the neutral grounding resistor 130 exceeds a pre-set threshold, the surge protector 128 will substantially immediately start conducting, alleviating the main plant equipment insulation stress caused by the voltage surge. The current through the surge protector 128 is to be limited below the generator 102 damage levels.

[0018] In the arrangement shown in Fig. 2, the surge protector 128 may further include the ability to trip one or both of the generator circuit breaker 106 and the bus tie circuit breakers 116. For example, the surge protector 128 may include one or more relay outputs 132 connected to one or more bus tie circuit breakers 116 and/or to the generator circuit breaker 106. Although the relay output 132 shown in Fig. 2 connects to both the generator and bus tie circuit breakers 106, 116, which may be by a single line or multi-line cable for separate control, separate relay outputs may be used for the different circuit breakers, where desired. Other like circuitry may be utilized instead to trip the generator and/or bus tie circuit breakers 106, 116 in response to a surge condition. For cases where it is desired to have the surge protection active based on the status of the generator circuit breaker 106 and/or the bus tie circuit breakers 116, a control circuit 142 may be provided to enable or disable the surge protector 128 by closing or opening, respectively, a circuit breaker 140 or the like. The surge protector 128 may be connected to an uninterruptible power supply (not shown) to receive power for operation, particularly during a surge event, although other methods of powering the surge protector 128 may be used as well.

[0019] Fig. 5 shows one example method 500 of the surge protector 128 responding to a surge event in the power generation and distribution system 100. The surge protector 128 may utilize logic circuitry, an ASIC, a dedicated controller, or other like control circuitry to implement various response actions in the event of a surge. At step 502, when a surge occurs in the system 100, the surge protector 128 or other like circuit will respond by conducting current on the generator 102 to ground 127. Simultaneously or shortly thereafter, at step 504, the surge protector 128 may further actuate the relay output(s) 132 to trip the bus tie circuit breakers 116, which may help to prevent the surge from propagating to other switchboards 108 within the power transmission system 100. At step 506, which may take place generally simultaneously with step 504, before step 504, or after step 504, the surge protector 128 may initiate a timer, which gives the surge an opportunity to dissipate before it becomes necessary to trip the generator circuit breaker 106 and possibly shut down the generator prime mover (diesel engine or the like). The timer is preferred to be for a duration greater than 30 milliseconds, or approximately 3 cycles longer than the circuit breaker opening time, including the trip coil activation time. A higher time limit may be selected as per the vessel specific protection devices selectivity philosophy.

[0020] At step 508, once the timer expires, the surge protector 128 will determine whether the surge protector 128 or like circuit is still conducting. If not, the surge in the power transmission system 100 is likely to have subsided and tripping of the generator circuit breaker 106 and/or shutting down the generator prime mover is likely unnecessary. Thus, at step 510, the timer may be reset. If the surge protector 128 or like circuit is still conducting at the expiration of the timer, at step 512, the surge protector 128 may actuate the relay output 132 to trip the generator circuit breaker 106, disconnecting the generator 106 from the respective switchboard 108. The generator circuit breaker 106 trip action may also be set to simultaneously shut down a generator excitation system (not shown) as well as the generator prime mover (diesel engine or the like) by activating an engine emergency stop circuit (not shown) or the like. Once the surge protector 128 or like circuit ceases to conduct, the timer may be reset.

[0021] In some arrangements, the timer may be removed and the generator circuit breaker 106 may be tripped at generally the same time as the bus tie circuit breakers 116. In other arrangements, the timer may cause a delay for tripping both the generator circuit breaker

106 and the bus tie circuit breakers 116, either generally simultaneously or sequentially. Multiple timers may be used, if necessary, to stagger the tripping of the generator circuit breaker 106 and the bus tie circuit breakers 116. Although not shown in Fig. 5, in this and other arrangements, the surge protector 128 may have one or more additional relay outputs (not shown) and may trip one or more of the load circuit breakers 110 to protect the load(s) 112. In such arrangements, the load circuit breakers 110 may be tripped generally simultaneously with the bus tie circuit breakers 116 and/or the generator circuit breakers 106, or may be tripped at some other time relative to the others. In some arrangements, as it may be the case for a surge protector activation while the generator circuit breaker 106 is open, the step 504 may be skipped and the timer 506 may be removed as the desired action may be to immediately shut down the generator excitation system and the generator prime mover, but it may not be desired to trip bus tie circuit breakers 116.

[0022] Fig. 3 shows an alternative surge protector deployment method for the same grounding system design shown in Fig. 2. The schematic in Fig. 3 includes a neutral grounding transformer connected between each one of the three (3) main distribution switchboards and vessel hull grounding through the surge protector. As described further herein, this grounding transformer will conduct current only during high unbalance voltage surges, that is: during normal operations or when the system is subjected to failure modes that would not give rise to overvoltage conditions beyond the system equipment voltage insulation capability, this transformer is not connected to ground. This alternative configuration may be preferred for cases where the surge protector 128 activation may cause excessive currents flowing through the generator 102 windings. Like numerals have been used in Fig. 3 to represent various components, except the 300 series numerals have been used. Accordingly, a complete description of the configuration shown in Fig. 3 has been omitted, with mainly the differences being described.

[0023] In this example, the generator 302 is provided in a more conventional arrangement, connected to the bus-tie cables 314 through generator circuit breaker 306. Neutral point 329 of the generator 302 is connected to ground 327 via the neutral grounding resistor 330.

Separately, the bus-tie cables 314 are connected in parallel to a neutral grounding transformer 331 through a transformer circuit breaker 352. The neutral grounding transformer 331 may include a resistor 350 connected across an open delta secondary winding 351. The surge protector 328 may be installed between the hull grounding 327 and a neutral lead of the grounding transformer 331 high voltage windings.

[0024] The arrangement shown in Fig. 3 may be configured to allow the surge protector 328 to conduct the overvoltage surge to ground without the excess current potentially passing through the windings of the generator 302 and damaging the generator 302. In normal operation, conventional system faults (e.g., caused by system unbalances, phase-to-ground faults, series faults, and the like) may be handled through the neutral grounding resistor 330, as usual. However, when the surge protector 328 on-voltage is exceeded during simultaneous unbalanced faults, intermittent phase to ground fault through high inductance, or like failure modes which can lead to excessive voltage between the system electrical neutral and ground, the surge protector 328 may begin conducting to suppress the fault voltage. The surge protector 328 may trip the generator circuit breaker 306 via the relay output 332. The surge protector 328 may also use the same or a different relay output 332 to trip the bus tie circuit breakers 316, if needed. The surge protector 328 may also include an additional relay output 334 that can allow the surge protector 328 to prevent the transformer overload protection system opening of the circuit breaker 352, ensuring that the grounding transformer 331 remains connected to the main power system 100 for the duration of the voltage surges. Moreover, the surge protector 328 may also operate load circuit breakers (not shown), where necessary. The resistor 350 provided in the grounding transformer 331 may serve to limit throughput current to the surge protector 328 in the event the ensuing current caused by the overvoltage surge may damage the grounding transformer 331. The ohmic value of the resistor 350 may be selected to ensure the surge protector 328 operation does not conflict with the power system 100 unbalanced fault protection operation based on the current through and voltage across the generator neutral grounding resistor 330. In other words, the resistor 350 may be sized to limit current through the surge protector 328 so that when the surge protector 328 is active, system electrical neutral is not matching the ground 327 voltage, which could cause malfunctioning of earth fault protection based on the generator's 302 neutral resistors. The surge protector 328 may handle just the overvoltage conditions that the protection needs to operate. For cases where it is desired to have the surge protector 328 active based on the status of the generator circuit breaker 306 and/or the bus tie circuit breakers 316, a control circuit 342 may be provided to enable or disable the surge protector 328 by closing or opening, respectively, a circuit breaker 340 or the like.

[0025] Referring to Fig. 4, the surge protector may also be deployed with an alternative grounding system configuration of the drilling vessel main power generation and distribution system that uses a neutral grounding transformer 431 connected between each main switchboard's bus bars 414 and hull grounding 427. Unlike the configuration shown in Fig. 3, the grounding transformer 431 in Fig. 4 is always connected to the system ground 427.

The grounding transformer 431 includes a resistor 450 installed between the open delta terminals of the transformer secondary windings. The resistor 450 ohmic value may be based on the total leakage capacitive current of the main power plant components (as defined in applicable standards, rules and regulations), that is: the sum of all leakage capacitive currents of all generators, all bus-tie cables and all feeder cables connecting the main switchboard 108 to each of the distribution transformers 112a. Like numerals have been used in Fig. 4 to represent various components, except the 400 series numerals have been used. Accordingly, a complete description of the configuration shown in Fig. 4 has been omitted, with mainly the differences being described.

[0026] Unlike the design shown in Fig. 3, where the grounding system protection is based on the high resistance ohmic value connected between the generator neutral 329 and hull grounding 327, the grounding system protection design shown in Fig. 4 is based on the high resistance ohmic value of the grounding transformer 431. The generator 402 may be connected to the main switchboard bus bars 414 through the generator circuit breaker 406. The bus bars 414 may be connected to a neutral grounding transformer 431 that may include a high ohmic resistor 450 connected across an open delta secondary winding 451. A transformer circuit breaker 452 may be provided between the bus bars 414 and the neutral grounding transformer 431. The surge protector 428 may be connected across the neutral grounding transformer 431, and specifically across the high ohmic resistor 450 thereof, in parallel with all protection and control equipment that requires the power system 100 unbalanced voltage feedback. The surge protector 428 may operate in a manner similar to the surge protector 128 described above, in that a detected surge will cause the surge protector 428 to conduct and the surge protector 428 may use relay outputs 432 to trip the generator circuit breaker 406 and/or the bus tie circuit breakers 416. The surge protector 428 may also include an additional relay output 434 that can allow the surge protector 428 to prevent the transformer overload protection system opening of the circuit breaker 452, ensuring that the grounding transformer 431 remains connected to the main power system 100 for the duration of the voltage surges. Moreover, the surge protector 428 may also operate load circuit breakers (not shown), where necessary. The surge protector 428 may need to limit its throughput current to ensure the surge protector 428 operation does not conflict with the power system 100 unbalanced fault protection operation based on the current through and voltage across the resistor 450. Similarly, the surge protector may need to limit its throughput current to ensure the ensuing current caused by the overvoltage surge may not damage the grounding transformer 431. For cases where it is desired to have the surge protector 428 active based on the status of the generator circuit breaker 406 or the bus tie breakers 416, a control circuit 442 may be provided to enable or disable the surge protector 428 by closing or opening, respectively, a circuit breaker 440 or the like.

[0027] It should be noted that the method provided in Fig. 5 is also compatible with the alternative example systems shown in Figs. 3 and 4, and may be modified as needed based on system requirements and limitations.

FIGURES

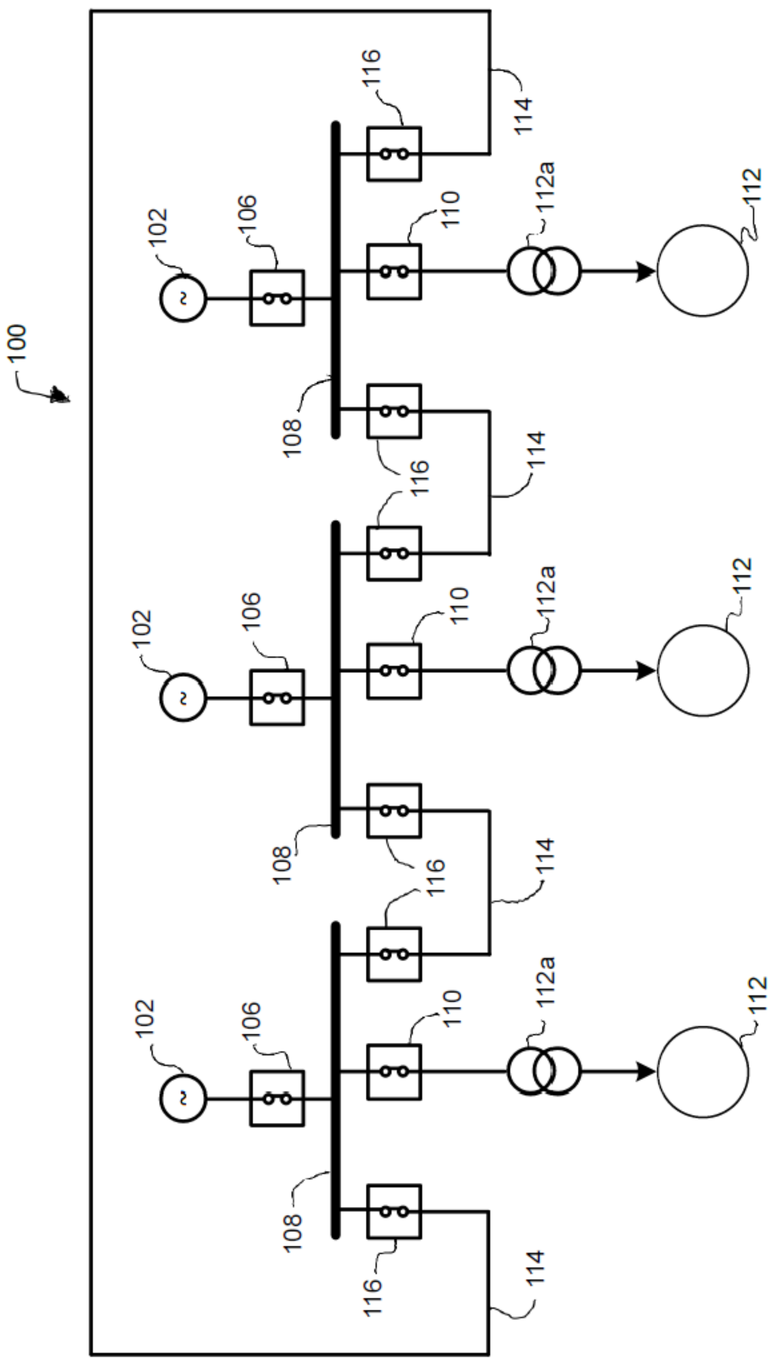

Fig. 1

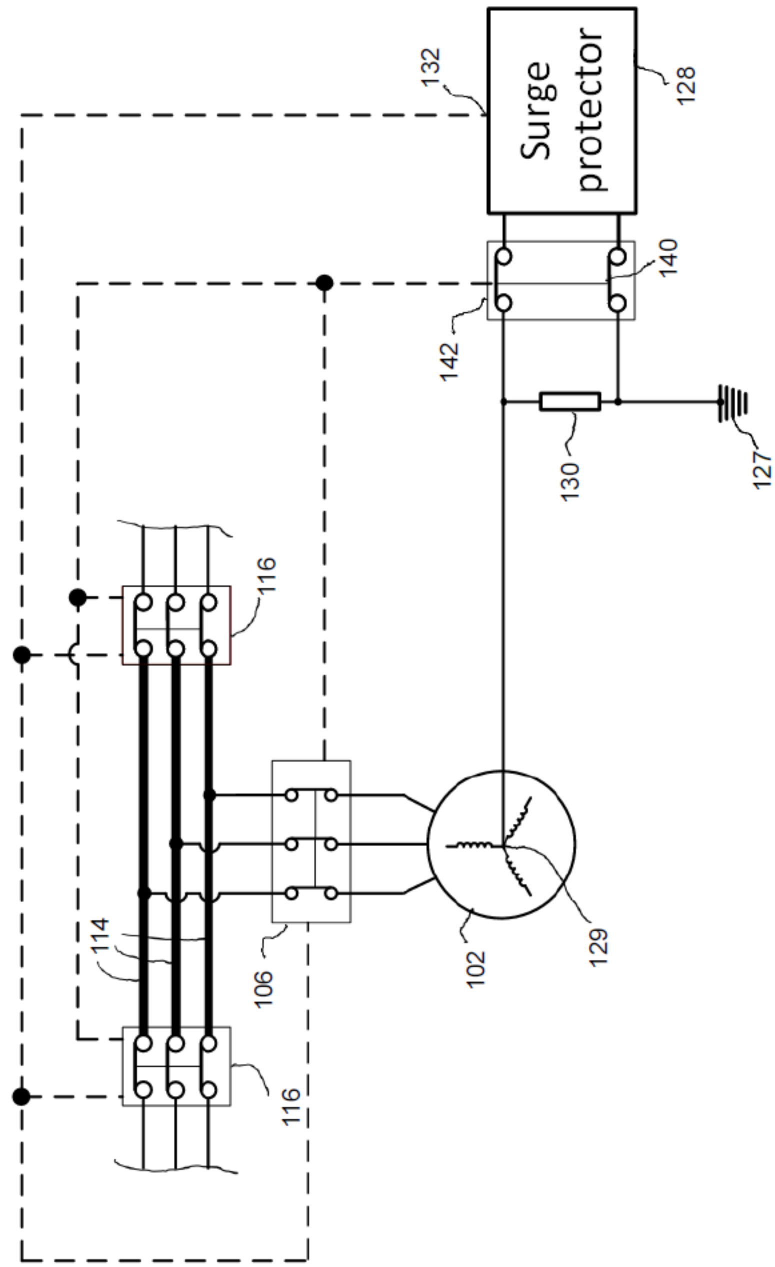
Surge protector
132
128
140
142
130
127
116
116
114
106
102
129

Fig. 2

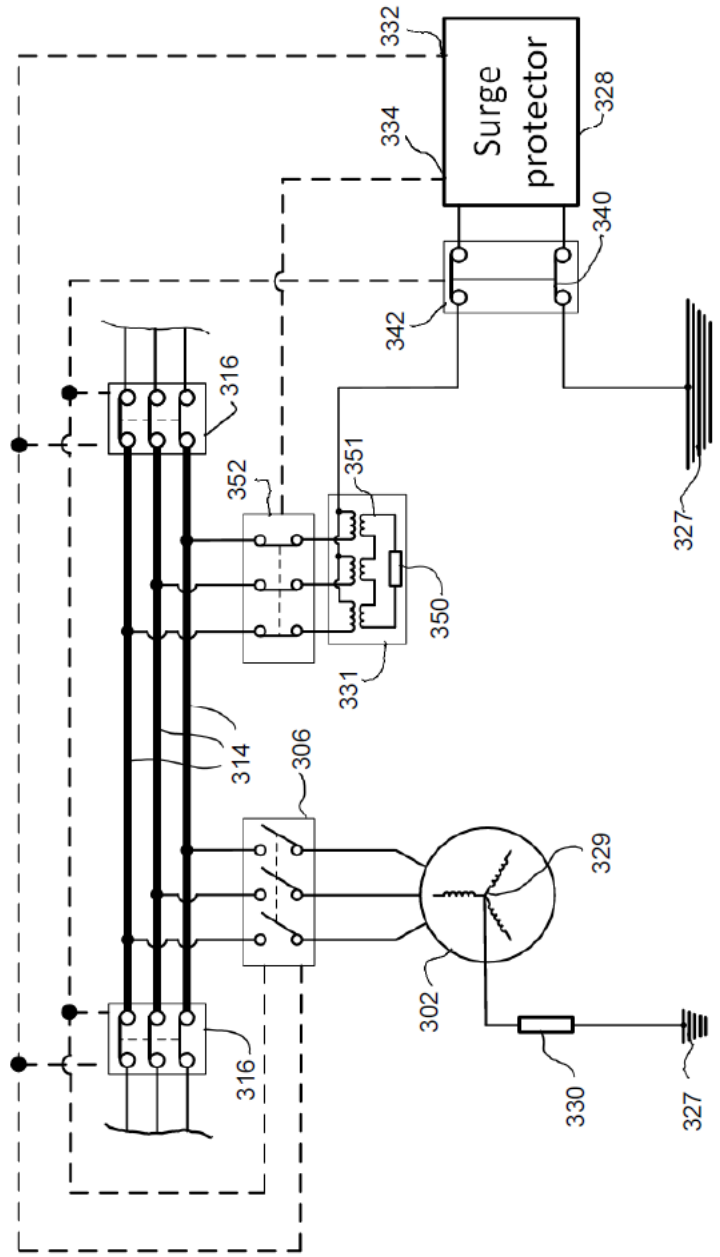
Surge protector
332
334
328
340
342
316
352
351
350
331
327
314
306
329
302
330

Fig. 3

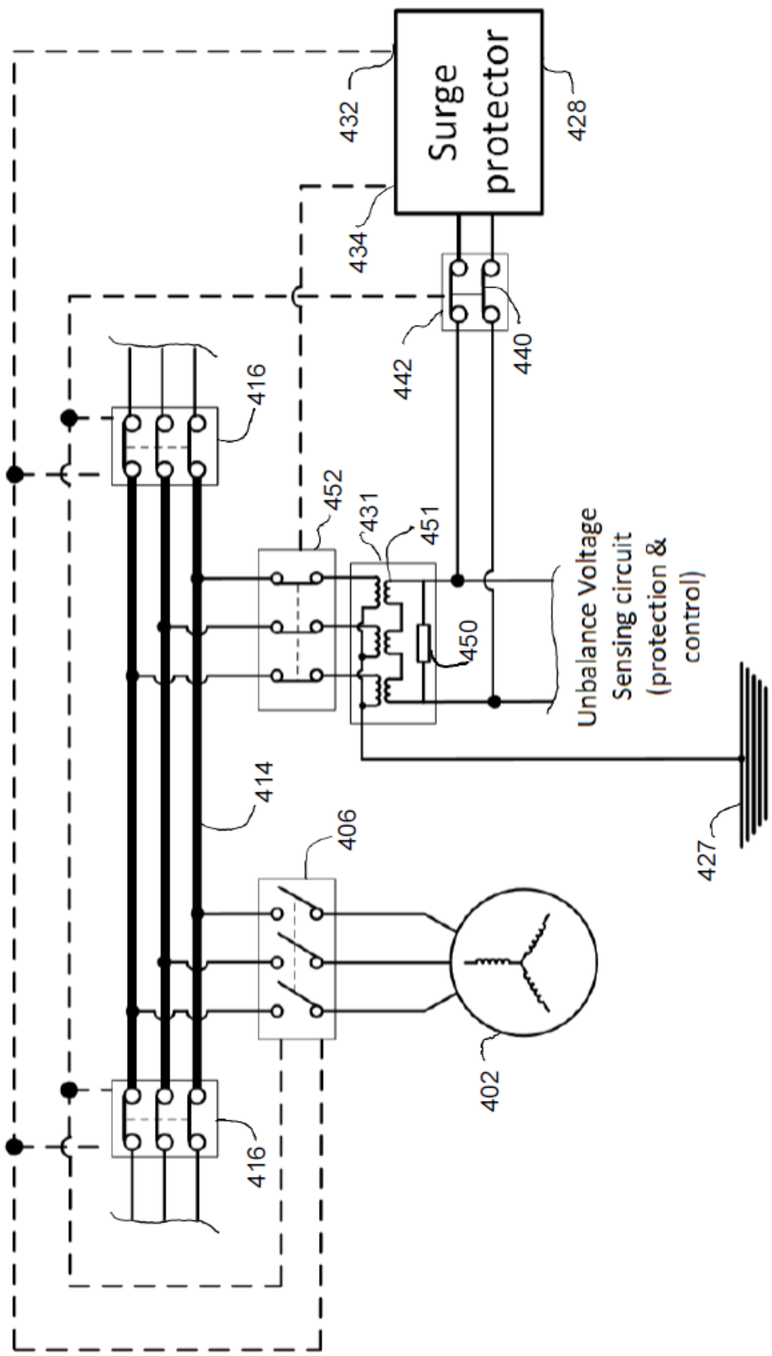
Surge protector
432
434
428
442
440
416
452
431
451
450
Unbalance Voltage Sensing circuit (protection & control)
414
406
427
402
416

Fig. 4

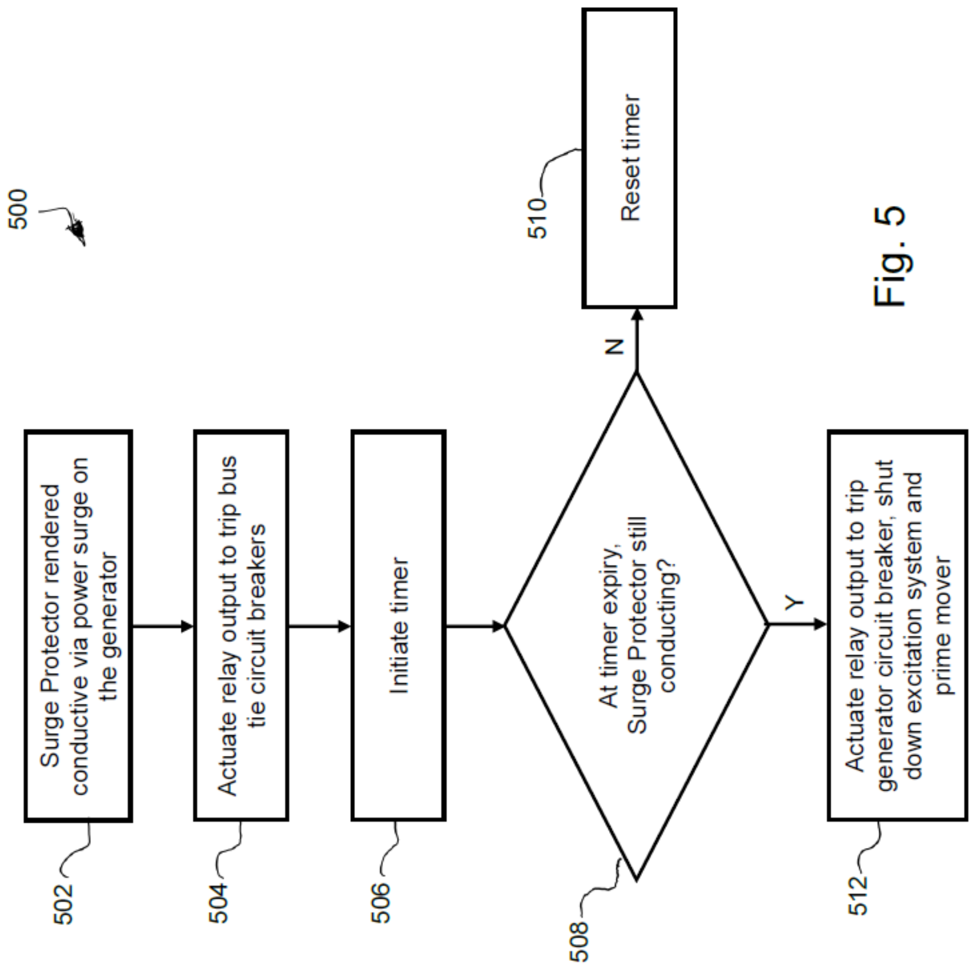
500
502
Surge Protector rendered conductive via power surge on the generator
504
Actuate relay output to trip bus tie circuit breakers
506
Initiate timer
508
At timer expiry, Surge Protector still conducting?
N
510
Reset timer
Y
512
Actuate relay output to trip generator circuit breaker, shut down excitation system and prime mover

Fig. 5